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MCAS EL TORO
SSIC NO. 5090.3.A

Subject:	IRP Site 1 – Aquifer Tests 3 and 4		
Prepared By:	Enviro Compliance Solutions, Inc. (ECS)		
Date:	October 18, 2005	Navy RPM:	Gordon Brown
Location:	Former MCAS El Toro	Site:	IRP-1
Contract:	N68711-04-C-1016		
Purpose:	Provide design criteria for remedial alternatives for groundwater impacted by perchlorate at IRP-1. Two areas (Zones 1 and 2) with elevated concentrations of perchlorate in groundwater occur within IRP-1. Perchlorate appears to migrate from these zones through a relatively narrow area at the downstream boundary of Zone 1 in the vicinity of the Borrego Wash tributary.		
Work Elements:	1. Measure groundwater levels and collect samples for analysis of perchlorate, major ions and total dissolved solids from IRP-1 wells, and for analysis of nitrate/nitrite and bacteria population enumeration at selected wells to establish pre-aquifer testing conditions. 2. Determine the depth profile for alluvium and install piezometers at the downstream limit of Zone 1 in the vicinity of the Borrego Wash tributary to assess mechanisms to mitigate downstream transport of perchlorate in groundwater. 3. Design, install and develop up to four extraction wells and up to three piezometers in Zones 1 and 2, conduct step-tests at each extraction well, conduct up to 72-hour constant discharge rate and recovery tests in Zone 2, and conduct up 90 days of testing and monitoring for Zone 1. Based on testing results, assess aquifer hydraulics, identify boundary conditions for Zones 1 and 2, and determine long-term extraction well yields. 4. Measure groundwater levels and collect samples for analysis of perchlorate at IRP-1 wells and bacteria population enumeration at selected wells to establish post-aquifer testing conditions. 5. Prepare reports documenting field protocols and project findings.		
Attachments:	Table 1: Proposed Well Completion Data Figure 1-Goundwater Levels and Perchlorate Plume – August 2005 Figure 2: Proposed Wells and Borings Exhibit A: Location Map Attachment 1-Progress Report for Perchlorate Microcosm Study for IRP Site 1, El Toro, CA.		

Objective

Groundwater level monitoring, groundwater sampling and analysis, and Aquifer Tests 1 and 2 were completed by ECS in June 2005 according to the approved workplan[1]. Monitoring, testing and sampling results were presented to the Base Closure Team (BCT) in June 2005. Based on the findings, one area with elevated perchlorate concentrations occurs within the center portion of IRP-1 in the vicinity of the Borrego Wash tributary (Zone 1), and a second area with elevated perchlorate concentrations occurs upslope within the southeast-central portion of IRP-1 (Zone 2). Perchlorate in groundwater from Zones 1 and 2 appears to migrate downgradient through an estimated 150-foot wide area in the vicinity of the Borrego Wash tributary (Figure 1).

According to the approved workplan, ECS initiated a three-month microcosm laboratory study in the summer of 2005 to evaluate organic cultures that could stimulate degradation of perchlorate and chlorinated hydrocarbons by native bacteria in groundwater. Based on interim findings to date, the testing laboratory reported that bacteria populations in groundwater samples collected in June 2005 were anomalously high, and additional groundwater sampling for bacteria was recommended[2].

Based on these findings, the following field-testing and sampling program is proposed.

[1] ECS, April 2005, Final Aquifer Characterization and Treatability Testing at Installation Restoration Program Site 1, Former Explosive Ordnance Disposal Range, Former Maine Corps Air Station El Toro, California: Environ Compliance Solutions, Inc., Santa Ana, CA.

[2] CytoCulture, August 29, 2005, Progress Report for Perchlorate Microcosm Study for IRP Site 1, El Toro, CA: CytoCulture International, Inc.: Point Richmond, CA

Field Sampling and Testing Program

The purpose of the field sampling and testing program is to:

- Collect and analyze groundwater samples from wells at IRP-1 to monitor temporal changes in groundwater elevation, quality and bacteria population.
- Assess perchlorate migration in groundwater from perchlorate Zones 1 and 2.
- Implement Aquifer Tests 3 and 4 in Zones 1 and 2 to assess source area remedial alternatives.
- Provide design criteria for remedial alternatives for groundwater impacted by perchlorate at IRP-1.

The field sampling and testing program is summarized by task below. Field procedures will be consistent with those referenced in the approved workplan and NAVY Clean Standard Operating Procedure (SOP) for aquifer testing[3] unless noted. Location of existing and proposed wells, and proposed borings are provided in Figure 2.

Task 1: Pre-Test Groundwater Monitoring

Groundwater levels will be measured and samples will be collected in accordance with the "Low Flow (Minimal Drawdown)" protocol specified in NAVY Standard Operating Procedure (SOP) 8 from IRP-1 wells[4] for analysis of:

- Perchlorate by EPA method 314.0.
- Major ions by EPA method 300.0.
- Total Dissolved Solids (TDS) by EPA method 160.1.
- Nitrite/Nitrate by EPA method 300.0 at selected wells (01-MW201, 01-MW202, 01-MW-205, 01-MW-210, 01-MW-219, 01-MW-223, 01-PZ-03, 01-PZ-04, 01-PZ-07 and 01-PZ-11).
- Heterotrophic bacteria enumeration assay using Brewers' agar medium at selected wells (01-EW-01, 01-PZ-07 and 01-PZ-10).

The results will establish IRP-1 groundwater quality and flow conditions prior to Aquifer Tests 3 and 4.

Task 2: Direct-Push Sampling

Direct-push borings are proposed along the Borrego Wash tributary downstream of Zone 1 to establish depth of alluvium in the area where perchlorate in groundwater appears to be migrating from Zone 1 (Figure 2). As currently planned, borings will be approximately 40 feet apart, and will be drilled to the depth of refusal or bedrock, whichever is shallower. Boring spacing and locations may be modified, as needed, based on field results.

Task 3: Extraction Well and Piezometer Installation

One extraction well (01-EW-03) in Zone 2 and three extraction wells (01-EX-04, 01-EW-05 and 01-EW-06) in Zone 1 are proposed in areas of highest perchlorate concentration in groundwater. Extraction wells will be positioned within 10 to 20 feet of existing monitoring wells so that these wells can be used to measure early-time decline in groundwater levels during subsequent aquifer testing. One piezometer (01-PZ-20)[5] is proposed within 10 to 20 feet of extraction well 01-EW-03 to provide suitable aquifer test data to assess hydraulic characteristics of the suspected boundary between Zones 1 and 2 (Figures 1 and 2). One double-nested piezometer (01-PZ-21A&B) will be placed in the vicinity of the Borrego Wash tributary near the downstream boundary of Zone 1. Well borings will be drilled using hollow-stem auger (HSA) drilling equipment and logged every five feet to the total depth. Proposed locations for extraction wells and piezometers are provided in Figure 2, and proposed well and piezometer details are summarized in Table 1. The precise location and design of double-nested piezometer 01-PZ-21A&B will be based on findings from Task 2.

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[3] Bechtel, November 2000, Standard Operating Procedure, Aquifer Testing, SOP 14 (Rev. 2): Bechtel National Inc., San Diego, CA

[4] At the request of the US Navy, this scope was completed in August/September 2005 to accelerate the project schedule.

[5] Lithologic log will be based on samples collected from nearby well 01-EW-03. No soil samples will be collected during drilling of well borehole.

After completion of Task 8 (see below), up to two extraction wells (01-EW-07 and 01-EW-06) and up to two piezometers (01-PZ-22 and 01-PZ-23) will be installed in the vicinity of existing monitoring well 01-MW-213 where perchlorate has been detected in groundwater in excess of 100 ug/L. Subsequent testing using these wells will establish design criteria for perchlorate remediation in this area.

Task 4: Step Tests

Groundwater levels will be monitored periodically at selected wells to establish pre-test trends in water levels, and one final round of ground water levels will be collected from all IPR-1 wells prior to aquifer testing. After groundwater monitoring is complete, four to six hour step tests will be conducted at each installed extraction well to select a constant discharge rate for each extraction well for the subsequent constant discharge rate tests.

Task 5: Aquifer Test 3

After the step tests, constant discharge rate and recovery tests will be conducted up to 72 hours using extraction well 01-EW-03. During the test, groundwater levels will be measured periodically at extraction and selected observation wells to assess aquifer transmissivity (T), hydraulic conductivity (k) and storativity for Zone 2, and assess boundary characteristics, if any, between Zones 1 and 2.

Task 6: Aquifer Test 4

Aquifer Test 4 will begin after the recovery phase for Aquifer Test 3 is complete. For Aquifer Test 4, extraction well 01-EW-04 will be pumped at a constant discharge rate for 60 days. For the initial 10 days of pumping, groundwater levels will be measured periodically at extraction and selected observation wells. During the 10th day of pumping, groundwater levels will be measured from additional monitoring wells to assess the radius of influence (ROI). These aquifer test results will be used to estimate Zone 1 aquifer transmissivity (T), hydraulic conductivity (k) and storativity, and quantitatively assess boundary characteristics, if any, within or near Zone 1.

After 10 days of pumping, extraction well 01-EW-05 will be brought on line, and after 20 days of pumping, extraction well 01-EW-06 will be brought on line. Both wells will be pumped at a constant discharge rate for the remainder of the test. Groundwater levels will be measured periodically at extraction and observation wells for the remainder of the test, and groundwater level drawdown maps will be prepared. The groundwater level drawdown maps will be used to assess the operational ROI as a function of time when three extraction wells are operating simultaneously during sixty days of pumping. After 60 days, pumping will cease or, depending on field conditions, may be extended to 90 days. After pumping, groundwater recovery will be measured for up to 30 days. The pumping and recovery phase of the test will be a total of 90 to 120 days.

Task 7: Post-Test Groundwater Monitoring

After 30 days of recovery, groundwater levels will be measured and groundwater samples will be collected from selected IRP-1 wells for analysis of:

- Perchlorate by EPA method 314.0.
- Heterotrophic bacteria enumeration assay using Brewers' agar medium at selected wells (01-EW-01, 01-PZ-07 and 01-PZ-10).

The results will establish IRP-1 groundwater quality after Aquifer Tests 3 and 4.

Task 8: Reports

The following reports will be provided.

- A Field Sampling and Analysis Report documenting well installations for Aquifer Tests 1 through 4, direct push sampling, and a summary of groundwater monitoring results. The report will include boring logs, water level measurements, and water quality data collected through August 2005.
- An Aquifer Test Report to include: 1) Test procedures, data analysis, and findings for Aquifer Tests 1 through 4, 2) Post-aquifer testing monitoring results, 3) Design discharge rates for extraction wells in perchlorate Zones 1 and 2, and 4) Feasible mechanisms to mitigate downstream migration of perchlorate.

Draft documents will be provided to the US Navy for review, and will be revised after comments are received.

Investigation Derived Waste

Soil cuttings from drilling of well borings, well development water and purge water from well sampling will be managed according to protocols contained in the approved workplan.

Schedule

The proposed field change justification tasks can be completed within six months of the authorization to proceed. Task scopes and schedule may be modified, as needed, to satisfy project objectives.

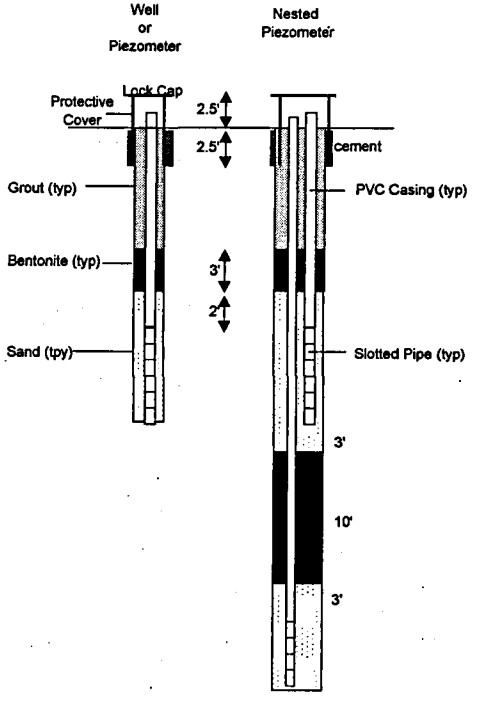
US NAVY Approval:	
Contractor: Enviro Compliance Solutions, Inc.	
By:	By:
Dhananjay Rawal, PE, Project Manager	Dan Herlihy, PG, CEG, CHG
Date: October 18, 2005	Date: October 18, 2005

TABLE 1
PROPOSED WELL COMPLETION DATA (DRAFT)

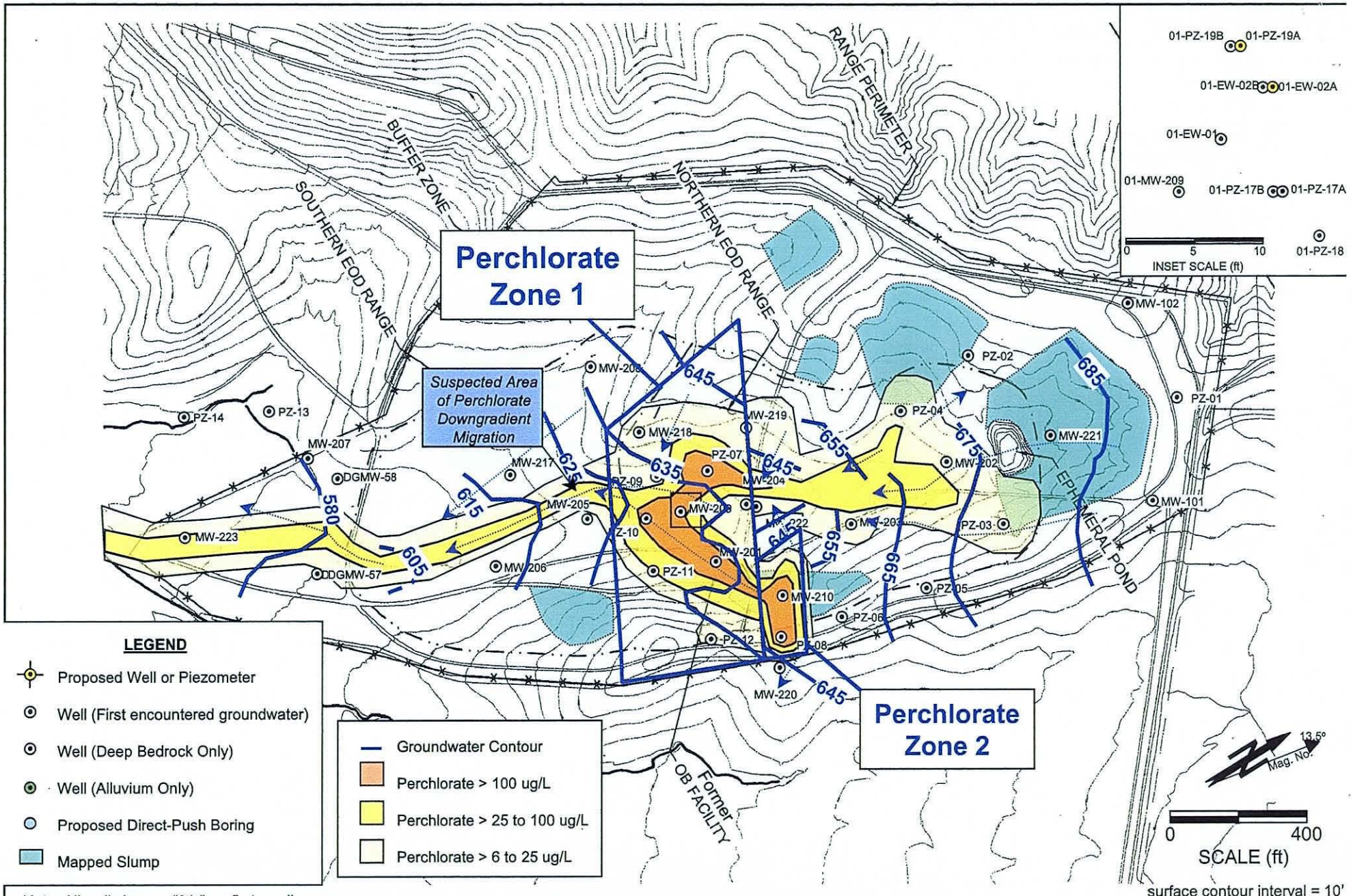
Installation Restoration Program - 1
Former Marine Corps Air Station - El Toro

WELL INSTALLATION						COMPLETION DATA													
Well Number	Appox. Elev.	Approx. DTW			Approx. Depth to Bedrock	Casing Diam (in)	Screen		Depth (ft)						Elevation (ft)					
	Grd	Sep '04	Jun '05	Aug '04			Slot	Length	Sand Pack		Slotted		Total Depth		Sand Pack		Slotted		Total Depth	
	ft (msl)	(ft)	(ft)	(ft)	(ft)		(in)	(ft)	Top	Bottom	Top	Bottom	Casing	Hole	Top	Bottom	Top	Bottom	Casing	Hole
Proposed Extraction Wells																				
01-EW-03	692.90	47	44	44	0	4	0.020	30	37	70	40	70	70	70	656	623	653	623	623	623
01-EW-04	662.10	39	26	27	4	4	0.020	35	22	60	25	60	60	60	640	602	637	602	602	602
01-EW-05	650.70	41	22	26	40	4	0.020	40	17	60	20	60	60	60	634	591	631	591	591	591
01-EW-06	667.20	47	38	37	17	4	0.020	35	32	70	35	70	70	70	635	597	632	597	597	597
Proposed Piezometers																				
PZ-20	692.90	47	44	44	0	2	0.020	30	37	70	40	70	70	70	656	623	653	623	623	623
PZ-21A	645.40	38	23	26	45	2	0.020	25	18	45	20	45	45	45	627	600	625	600	600	600
PZ-21B						2	0.020	10	52	65	55	65	65	65	593	580	590	580	580	580

Grd = Ground Surface



CROSS SECTION DIAGRAM



Note: All wells have a "01-" prefix to well name

ECS

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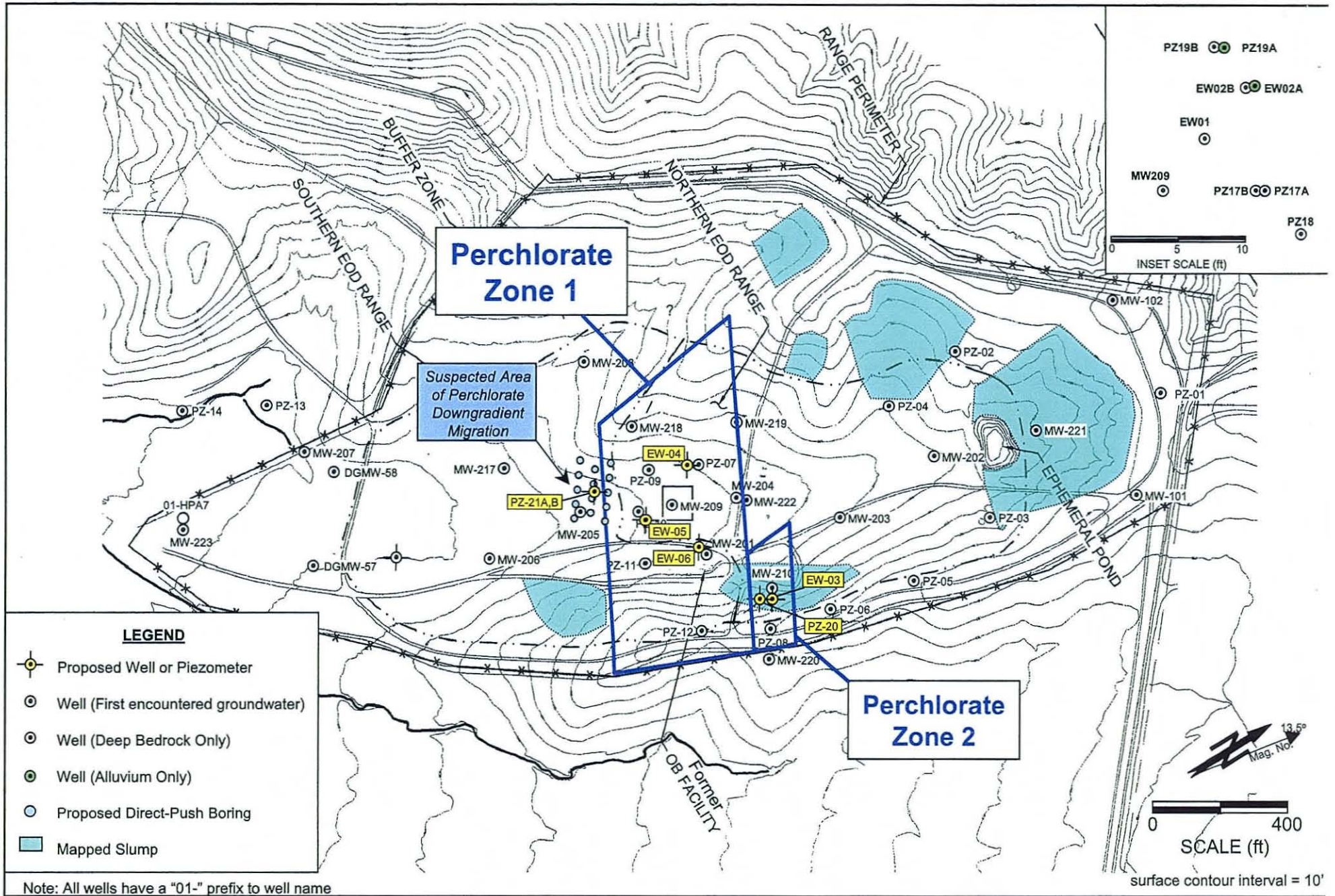
REA #224, CEM #1808

GROUNDWATER LEVELS & PERCHLORATE PLUME – AUGUST 2005

Installation Restoration Program – Site 1
Former Marine Corps Air Station
El Toro, CA

FIGURE 1



Note: All wells have a "01-" prefix to well name

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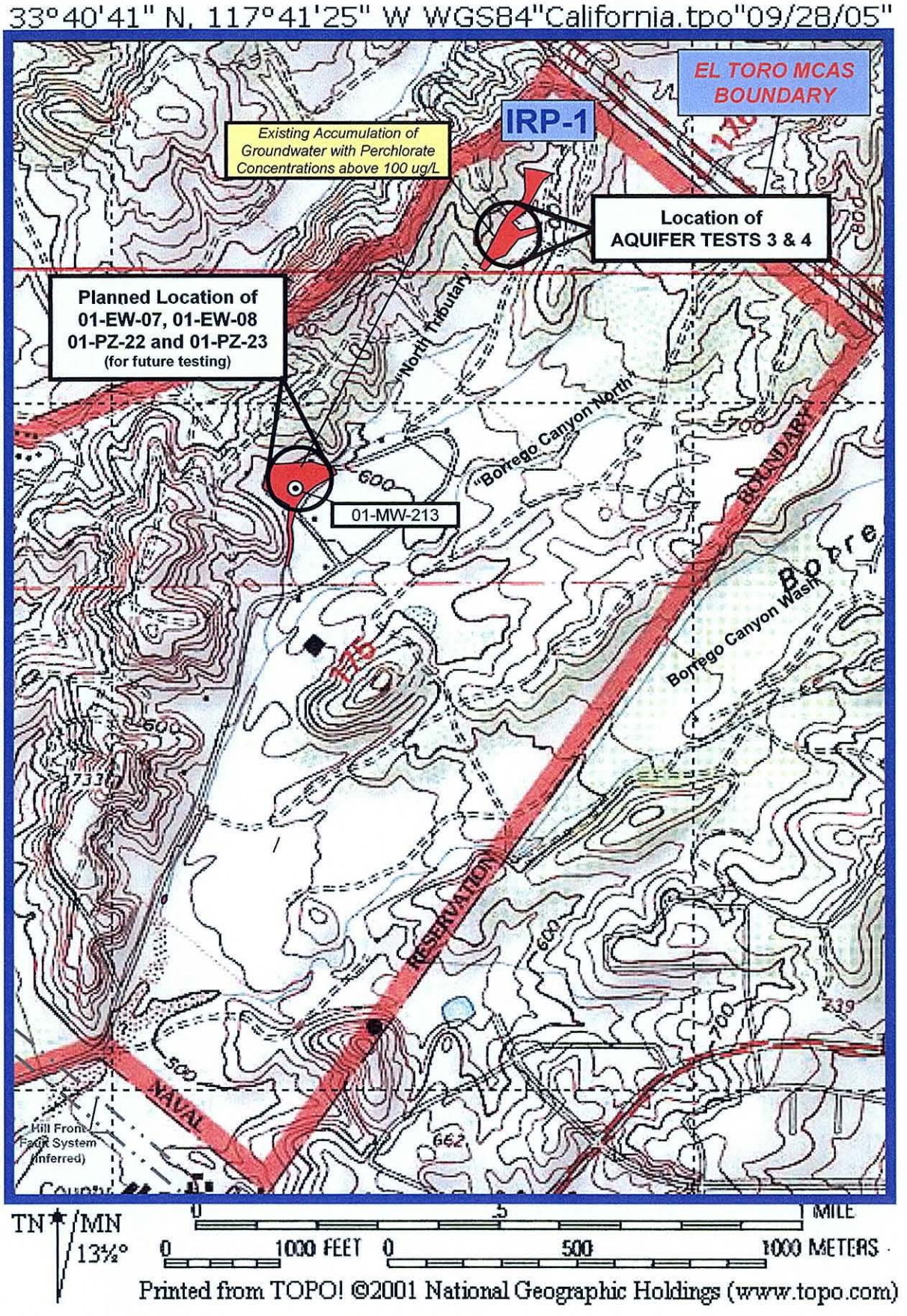
PROPOSED WELLS AND BORINGS

Installation Restoration Program – Site 1
Former Marine Corps Air Station
El Toro, CA

FIGURE 2



ECS Prepared by: Dan Herlihy RG #4388, CEG #1378, CHG #107, REA #224, CEM #1808	**LOCATION MAP** Installation Restoration Program – Site 2 Former Marine Corps Air Station El Toro, CA	**EXHIBIT A**

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August 29, 2005

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Progress Report for Perchlorate Microcosm Study for IRP Site 1 El Toro, CA

CytoCulture initiated an anaerobic perchlorate biodegradation microcosm screening study on June 23, 2005 using a composite of groundwater samples and soil obtained from IRP Site by Enviro Compliance Solutions (ECS) in El Toro, CA.

Four groundwater samples and seven soil samples were collected by ECS during the installation of groundwater monitoring wells at the site in the days immediately before June 23, 2005. The groundwater samples were collected in the field in such a way as to minimize agitation of the water flowing into sample containers from a low-flow monitoring well sampling pump. Sample bottles (a total of 1 liter each in two 500 ml polypropylene wide mouth bottles per groundwater sample) and 7 soil sleeves (capped) were shipped overnight to CytoCulture in a cooler packed with ice (no preservatives). The samples were stored at 4 Deg. C. until the microcosms were set up under anaerobic conditions on June 30, 2005.

Groundwater and Soil Sample Processing

In the CytoCulture lab, the 4 pairs of 500-ml poly bottles containing the four groundwater samples were brought to room temperature and opened inside the anaerobic glove box under an atmosphere of 5% hydrogen, 10% carbon dioxide and 85% nitrogen. The samples of groundwater were combined in a 4-liter plastic beaker in the anaerobic glove box on a magnetic stirrer. In the anaerobic glove box, 15 grams of soil were removed from the center of each of the seven soil sleeves and added to the stirring groundwater to generate a 5% soil slurry. The soil slurry was purged with a stream of nitrogen gas for 60 minutes while stirring to reduce levels of dissolved oxygen (DO) before proceeding with the study. After the nitrogen purging, the groundwater-soil slurry was allowed to stand so the majority of the soil particles could settle out. The groundwater supernatant of the slurry was decanted and used to inoculate the VOA vial microcosms with bacteria from the site. No other bacteria were introduced to the experiment.

The composite slurry was assayed for Total Anaerobic Heterotrophic Bacteria (report generated on July 15, 2005 – attached as an appendix to this report).

Microcosm Study Set Up

The experimental design called for testing one composite groundwater-soil slurry with 5 test conditions over 5 time points. Each microcosm was performed in duplicate, so there were 2 x 5 x 5 = 50 VOA vials (40ml each) in total. The electron donors were calculated to achieve a 5,000 ppm concentration to ensure all available electron acceptors are used up and to provide ample carbon sources to boost the growth of anaerobic bacteria.

5 Test Conditions to include 3 different electron donors (carbon sources):

- Monitored Natural Attenuation (MNA): groundwater slurry and buffer only
- Sodium Lactate at 5,000 ppm
- CytoSol BioSolvent at 5,000 ppm
- Molasses at 5,000 ppm
- Negative Control: groundwater slurry and sterile water, heat inactivated

These conditions are being tested over 5 time points (duplicate vials for each point):

- Time zero (was actually day 4), 4 weeks so far; then the study would have continued out to 8 weeks, 12 weeks and 16 weeks

This interim progress report has been prepared after the 4 week time point.

Each VOA vial (42ml capacity) was inoculated with 35 ml of the groundwater-soil slurry supernatant (decanted to remove the majority of the soil after one hour of stirring). A 3.2 ml, 3.84 ml or 4.0 ml aliquot of an anaerobic minimum salts medium was then added to the vials (depending on the dose volume of the electron donor) except for the negative control (sterile spring water was used instead for the negative control).

Electron donors (carbon sources) were then introduced as follows to achieve 5,000 ppm:

A. Monitored natural attenuation microcosms: No added electron donor
B. Lactate microcosms: 800 µl of a 20% (200,000 ppm) solution of sodium lactate.
C. CytoSol microcosms: 160 µl (200 mg) of neat 100% BioSolvent (0.87 g/ml)
D. Molasses microcosms: 300 µl of 20% (200,000 ppm) molasses in sterile water.
E. Negative control microcosms: No added electron donor

Microcosm Test Conditions (Electron Donors) in duplicate vials, 6 time points	Groundwater Slurry Inoculum	MSM Buffer	Electron Donor (%)	Perchlorate 8 mg/l (ml)	Total Volume
A. MNA (none)	35 ml	4 ml	None	1 ml	40 ml
B. Lactate 5,000 ppm	35 ml	3.20 ml	800 µl(20%)	1ml	40 ml
C. CytoSol 5,000 ppm	35 ml	3.84 ml	160 µl neat	1ml	40 ml
D. Molasses 5,000 ppm	35 ml	3.20 ml	800 µl(20%)	1ml	40 ml
E. Negative Control	35 ml	4 ml wtr	None	1ml	40 ml

Perchlorate Spike

After the addition of the electron donors, 1 ml of a solution of 8 mg/l ammonium perchlorate was added to each of the conditions that contained electron donors (conditions A-D) to achieve a final concentration of approximately 200 ug/l. The microcosm vials were capped and sealed tight prior to passing them out of the anaerobic glove box with the exception of the negative control. The negative control (condition E) was placed in boiling water for 10 minutes after being passed out of the anaerobic hood to inactivate most living bacteria; it was then cooled overnight in the shaker before adding the perchlorate solution. The negative control is not technically a true abiotic (poisoned) negative control since it consists of groundwater from the site but does not contain reagents such as azide, mercury and other toxic materials commonly used to kill bacteria since these reagents could interfere with chemical analysis of the perchlorate.

Each vial had a headspace of approximately a milliliter to assist with continuous mixing (horizontally in a shaker incubator) and allow for some compression space as gases are generated by anaerobic respiration.

Shaker-Incubation

All 50 microcosm vials were then placed in a rack box and positioned so the vials shake horizontally in a shaker-incubator operated at 100 rpm at ambient temperature.

Time zero samples were left to mix and reach steady state conditions overnight in the incubator before being delivered to the analytical laboratory the next business day for analysis by EPA method 314.0 (actually tested four days from the inoculation).

The rest of the vials were left shaking in the incubator. At each time point, a set of 5 vials (conditions A-E) is removed for analysis, placed in an iced cooler and delivered to Curtis & Tompkins, Ltd. Laboratory in Berkeley for the analyses.

Microcosm Results at 3 Weeks

Initial results at 3 weeks indicate there is a statistically significant decrease in perchlorate concentrations among the 5 test conditions relative to the negative control as indicated in the table below.

Microcosm Test Conditions (Electron Donors) in duplicate vials, 6 time points	[Perchlorate] Time = 1 **Day 3** ug/l	[Perchlorate] Time = 2 At **3 weeks** ug/l	Reporting Limit ug/l
A. MNA (none)	180	ND	8
B. Lactate 5,000 ppm	67	ND	8
C. CytoSol 5,000 ppm	190	ND	8
D. Molasses 5,000 ppm	53	ND	8
E. Negative Control	190	ND	8

Interim Conclusions at 3 Weeks

High Bacteria Populations

Analysis for total anaerobic heterotrophic bacteria in the composite ground water slurry indicated a surprisingly high population density of 6×10^6 bacteria colony forming units per milliliter. This high density of bacteria growing under anaerobic conditions suggests the presence of dissolved organic material in the groundwater to support (provide electron donor material) so many organisms.

Rapid Perchlorate Biodegradation

All of the microcosms (5 conditions, 6 time points) were spiked with 200 ug/l perchlorate. However, at the first time point, which was day 3 (not a true time zero sample), the levels of perchlorate had already begun to decline in the microcosms with the two conventional electron donors: lactate (67 ug/l) and molasses (53 ug/l). The other three microcosms (MNA, CytoSol and negative control) remained stable in the range of 180-190 ug/l as would have been expected for all the samples at this early time point.

By 3 weeks, the perchlorate had been consumed in all five conditions of microcosms. Even the negative control (presumably heat inactivated) appeared to have degraded all the perchlorate to ND levels, less than 8 ug/l (the reporting limit).

Given the unusually high population density of anaerobic bacteria (6×10^6 cfu/ml) in the groundwater slurry, it may not be so surprising in retrospect that the perchlorate biodegradation activity is so high. Background levels for aerobic and anaerobic bacteria at sites in California are generally 10^1 to 10^2 cfu/ml. At more typical contaminated groundwater sites, when higher levels of contaminants or organic carbon are present, the bacteria levels may be in the range of 10^4 to10^6 cfu/ml, so this site groundwater is definitely on the high end of the expected bacteria population density range we normally observe. Fortunately, the high bacteria population is working in favor of biodegradation.

Although the groundwater negative control sample was presumably heat-inactivated by immersion in boiling water for 10 minutes, it appears that after 3 weeks the surviving

bacteria were still able to biodegrade the perchlorate down to non-detectable levels. There must have been sufficient levels of dissolved organic carbon in the groundwater to sustain the higher density of bacteria and allow the facultative organisms to consume the perchlorate as an alternate terminal electron acceptor since we had already depleted the oxygen in these microcosms.

Further Experimentation with the Remaining Microcosms

The study so far has consumed 2 out of the original 5 sample sets. Three sets (3 time points) remain in the shaker incubator, and could be re-spiked with perchlorate. The negative control could be amended with azide to further inhibit bacterial growth.

Based on the interim findings, CytoCulture recommends the following:

1. CytoCulture will re-spike the remaining three samples with a higher dose of ammonium perchlorate to achieve a final concentration of 750, 550 and 350 ug/l perchlorate, respectively, and incubate for 2 weeks to determine to what extent the remaining bacteria in the microcosms could degrade the additional perchlorate in that time. The data would provide relative extents of biodegradation, not rates.

2. ECS should collect and properly preserve additional groundwater samples from the same area of the aquifer, so that CytoCulture can perform anaerobic heterotrophic bacteria enumerations to determine how anaerobic heterotrophic bacteria population densities may vary with season. These additional data would corroborate the previous findings, or indicate if anaerobic heterotrophic bacteria population is seasonally dependent.

The microcosm experimental results to date suggests that there is strong potential for in situ biodegradation of the perchlorate contaminants once the groundwater reaches anaerobic conditions.

Please let us know if you wish to proceed with our recommendatoins.

Sincerly,

Randall von Wedel

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